Predicting FF CO_2 fluxes using top-down NOx and CO emissions estimated from multi-constituent chemical data assimilation

Air quality + GHG

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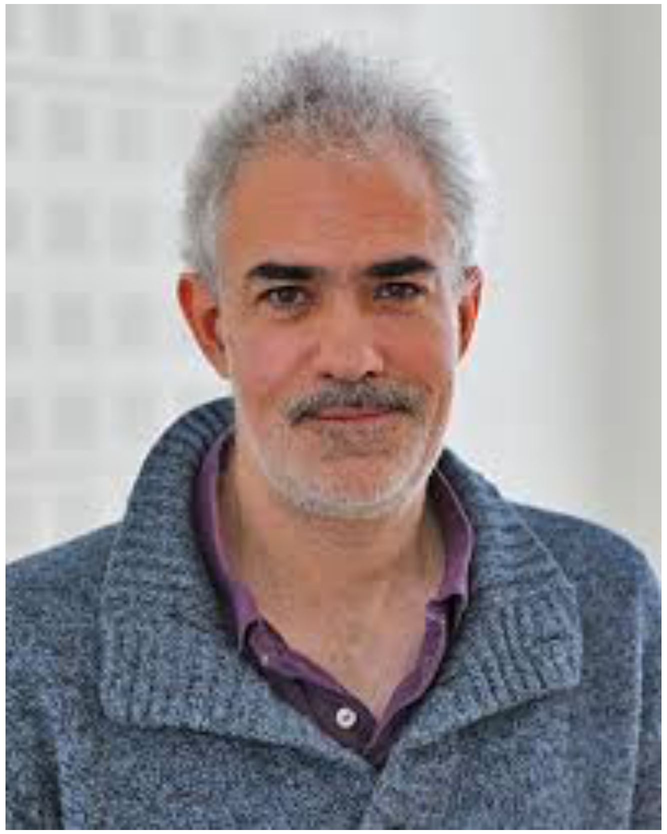
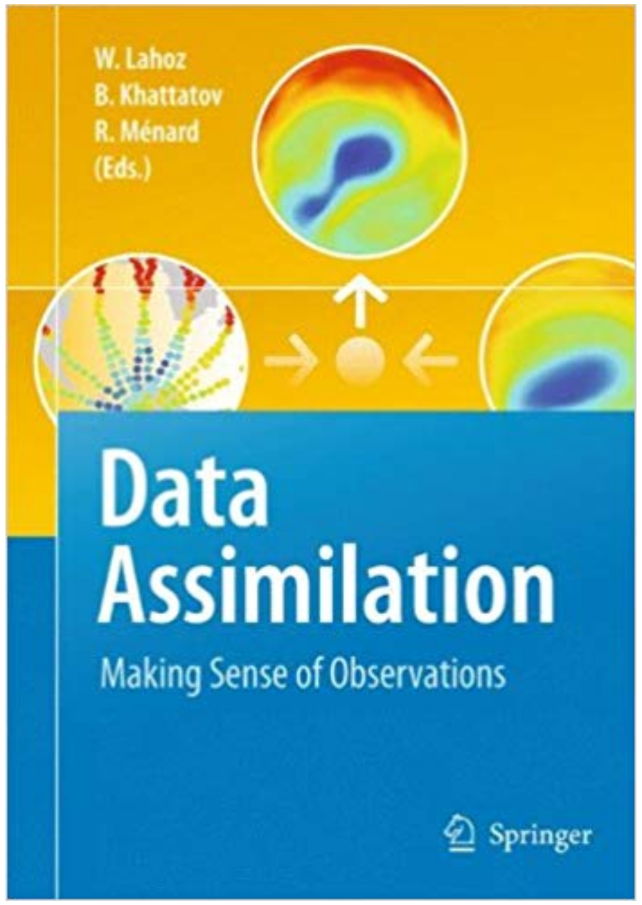


Dr. William Lahoz
1960-2019



Air quality

Edo Bridge
東都江戸橋日本橋 (歌川広重)

GHG

- OH coupling (CH_4)
- Combustion process (NO_x, CO, CO_2)
- Joint emission optimization

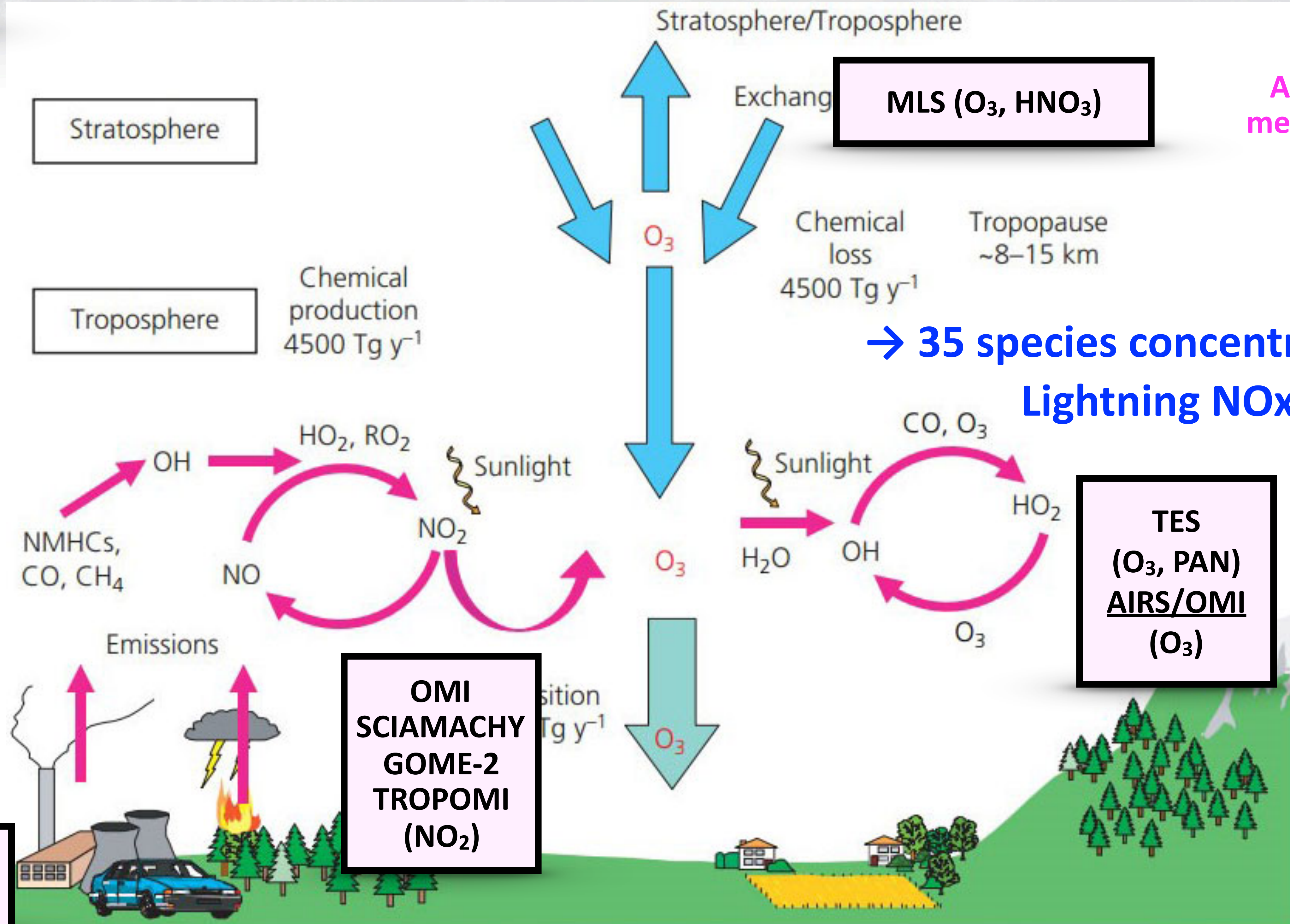
Reuter et al., 2019	The use of proxy species (NO_2, CO) for CO_2 flux estimates: Contain a strong signal associated with human activities
Silva and Arellano, 2017, Tang et al., 2019	AQ-GHG emission ratios can be used to understand emission processes (combustion type, new technology and regulation) and improve bottom-up inventories
Konovalov et al., 2016	Emission ratios can be used in hybrid emission estimations (e.g., from top-down NOx to CO_2)

Multi-constituent chemical reanalyses + **GHG inventories**

Multi-constituent chemical data assimilation

AQ

through ingestion of a suite of measurements from multiple satellite sensors



MLS (O_3, HNO_3)

Assimilated measurements

→ 35 species concentrations + Lightning NOx

TES (O_3, PAN) AIRS/OMI (O_3)

OMI SCIAMACHY GOME-2 TROPOMI (NO_2)

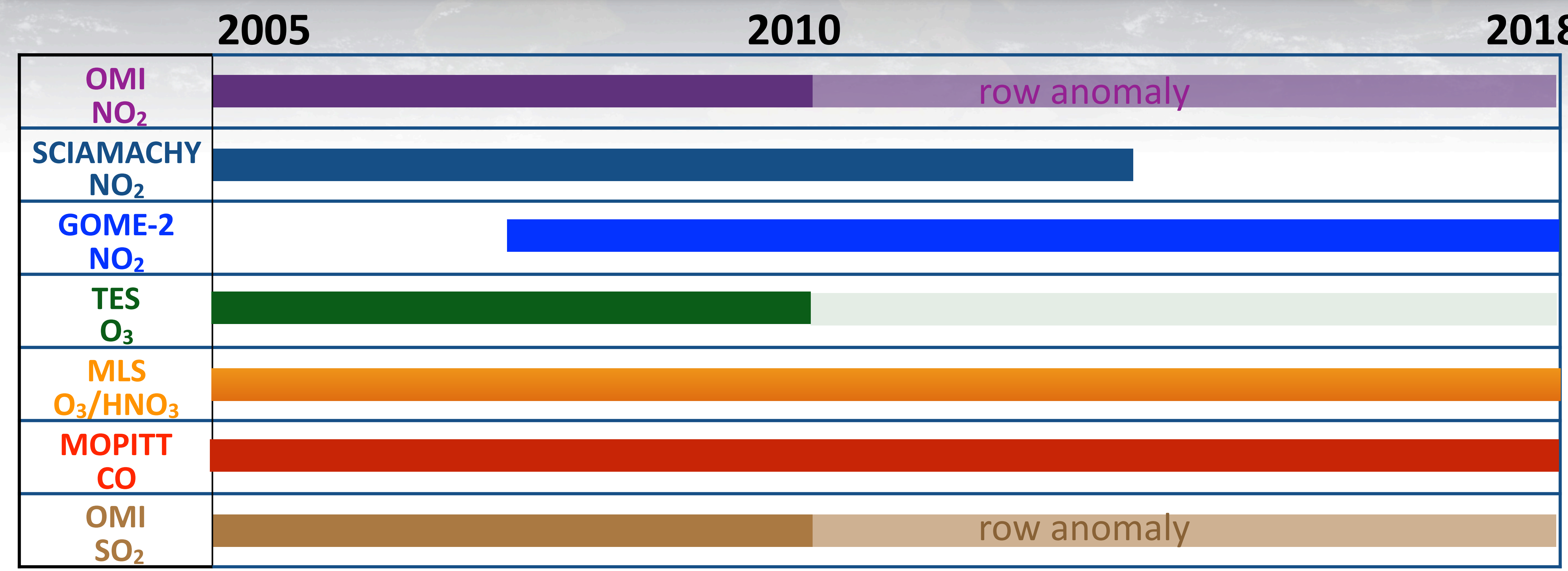
MOPITT (CO)

OMI (SO_2)

→ NOx, CO, SO_2 emissions

Miyazaki et al., 2012, 2013, 2014, 2017, 2019

Tropospheric chemistry reanalysis (TCR-2)



Two-hourly,
1.1°x1.1° resolution,
up to 70 hPa level

(1) understand the processes controlling the atmospheric environment

(2) provide initial/boundary conditions for climate/chemical simulations

(3) evaluate climate models and bottom-up emission inventories

(4) suggest developments of models/observations (e.g., satellite concepts)

AIRS Atmospheric Infrared Sounder — **O_3 (AIRS/OMI)**

OMI — **NO_2 (QA4ECV)**, **SO_2 (NASA PCA)**

GOME-2 Global Ozone Monitoring Experiment — **NO_2 (QA4ECV)**

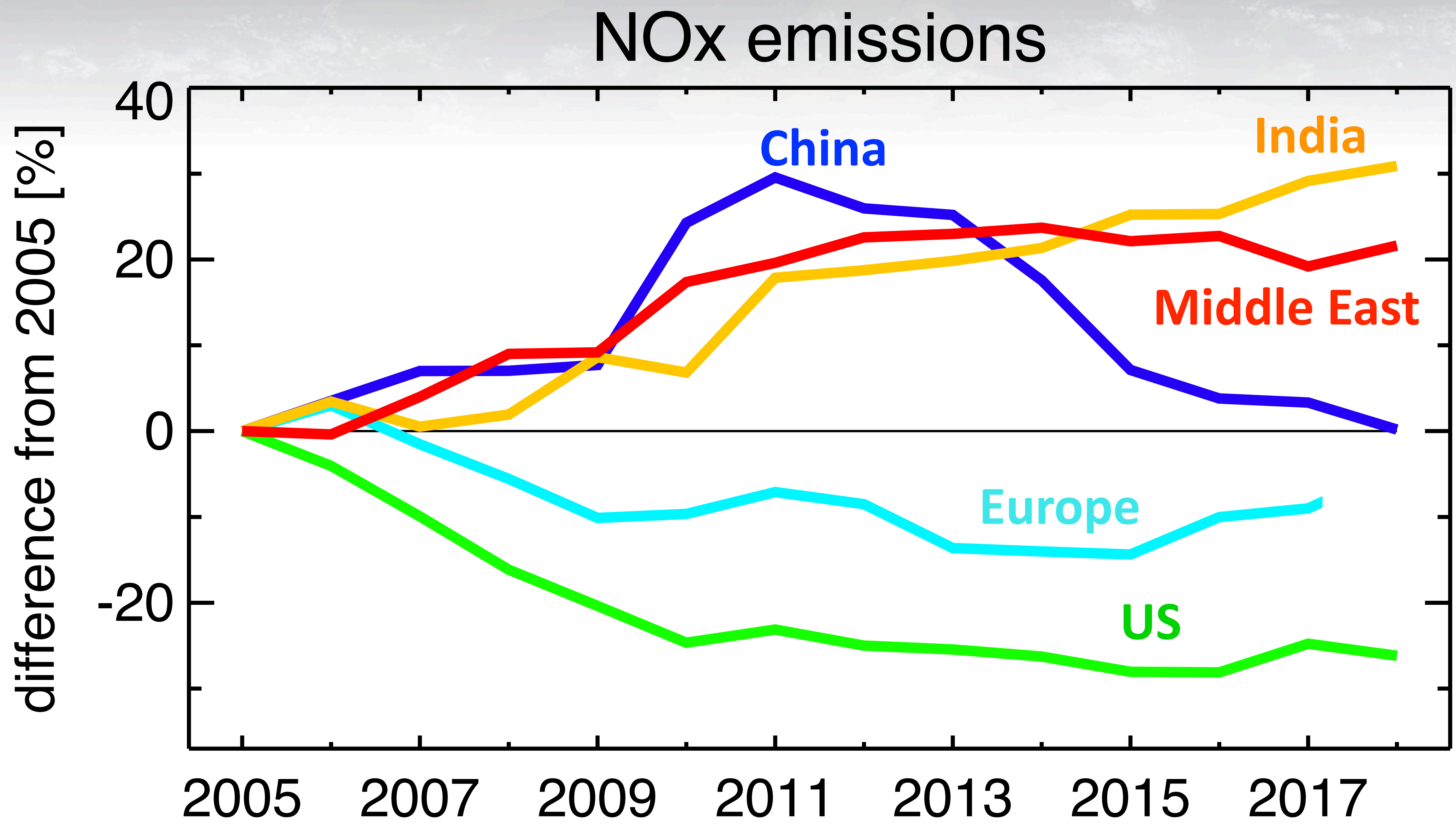
SCIAMACHY Scanning Imaging Absorption Spectrometer for Atmospheric Cartography — **NO_2 (QA4ECV)**

O_3 (v6)

MOPITT Measurements Of Pollution In The Troposphere — **CO (v7J)**

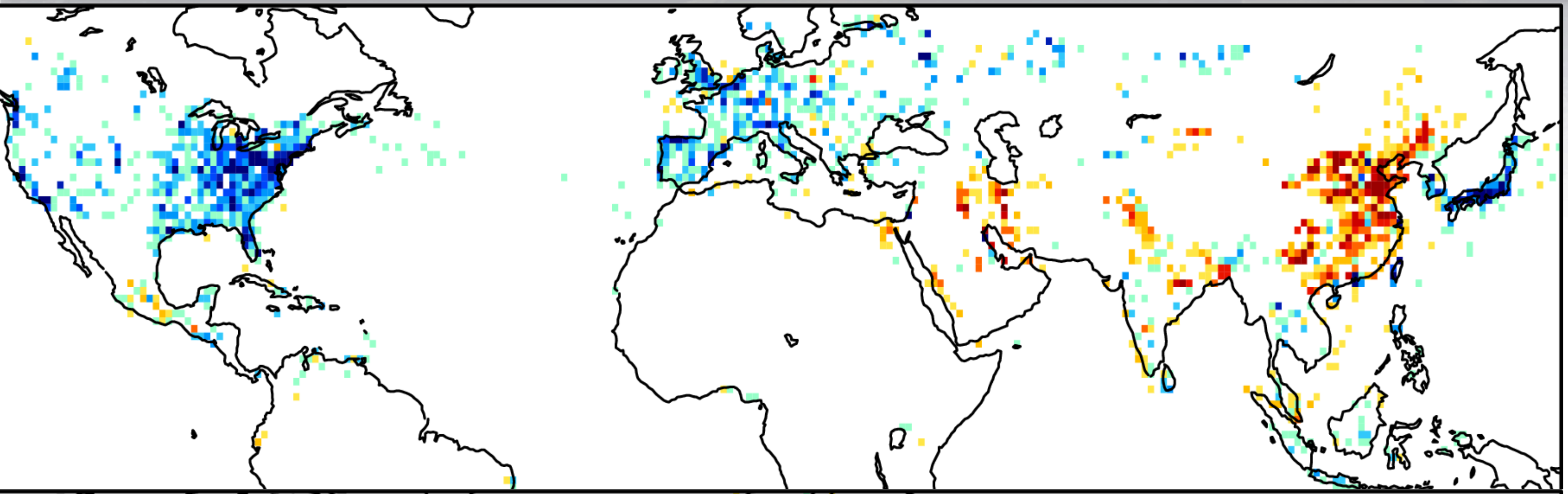
EOS MLS to study Earth's ozone and climate — **O_3, HNO_3 (v4.2)**

Global NOx emission trends (2005-2018)

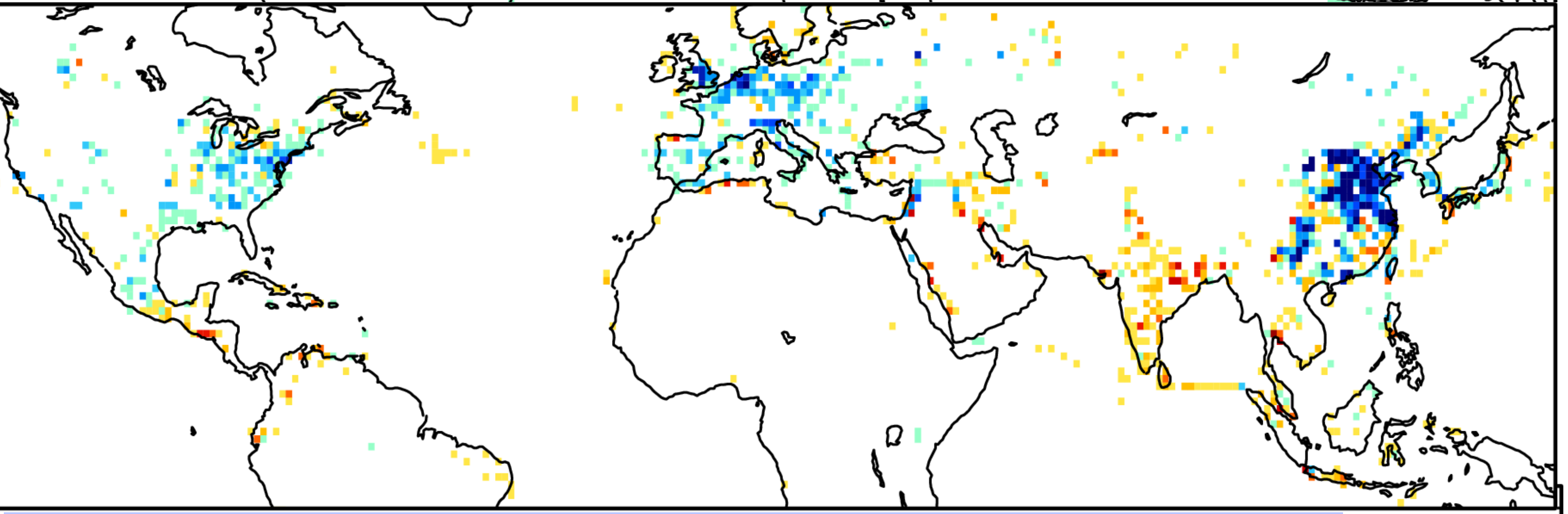


TCR-2 performance has been evaluated using various independent data (Miyazaki et al., in prep)

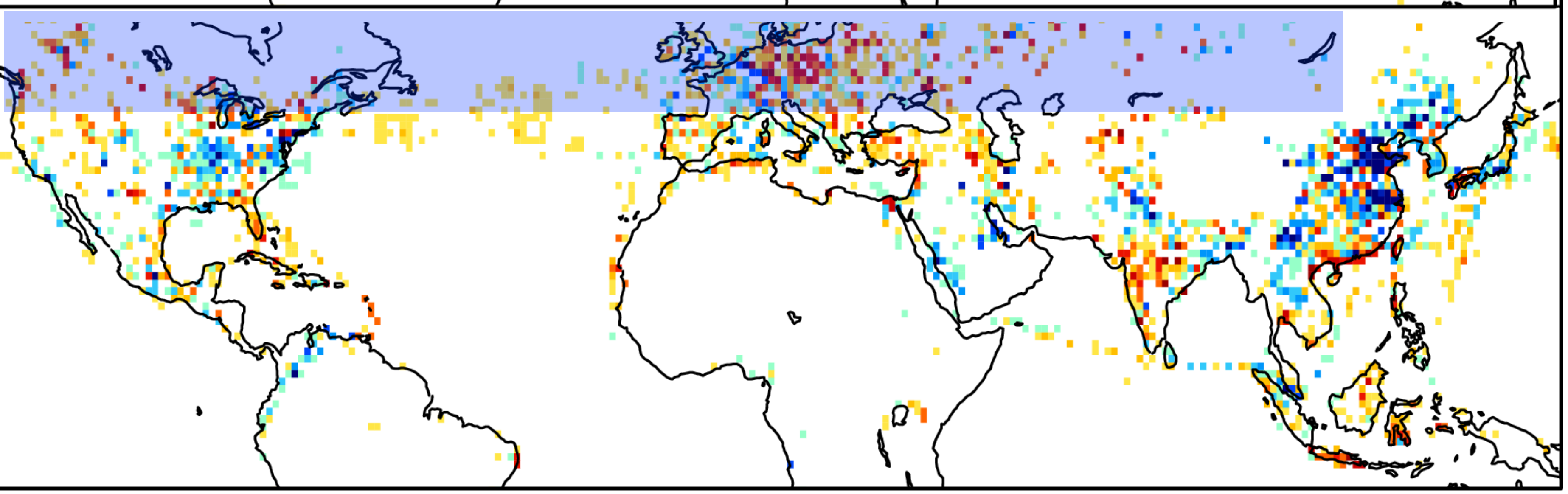
Global NOx emission trends (2005-2018)



2005-2010



2010-2015

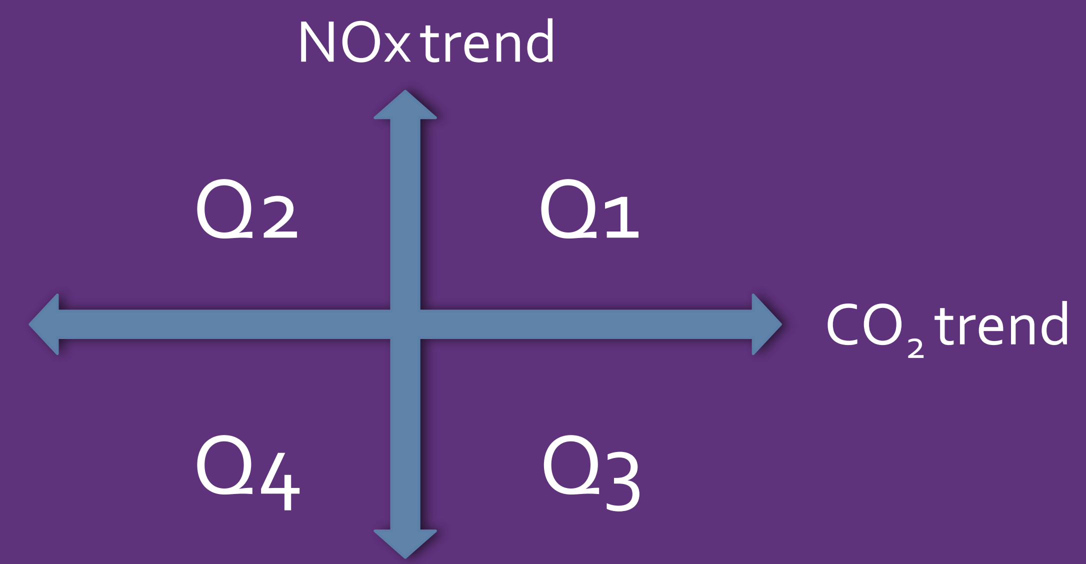


2015-2018

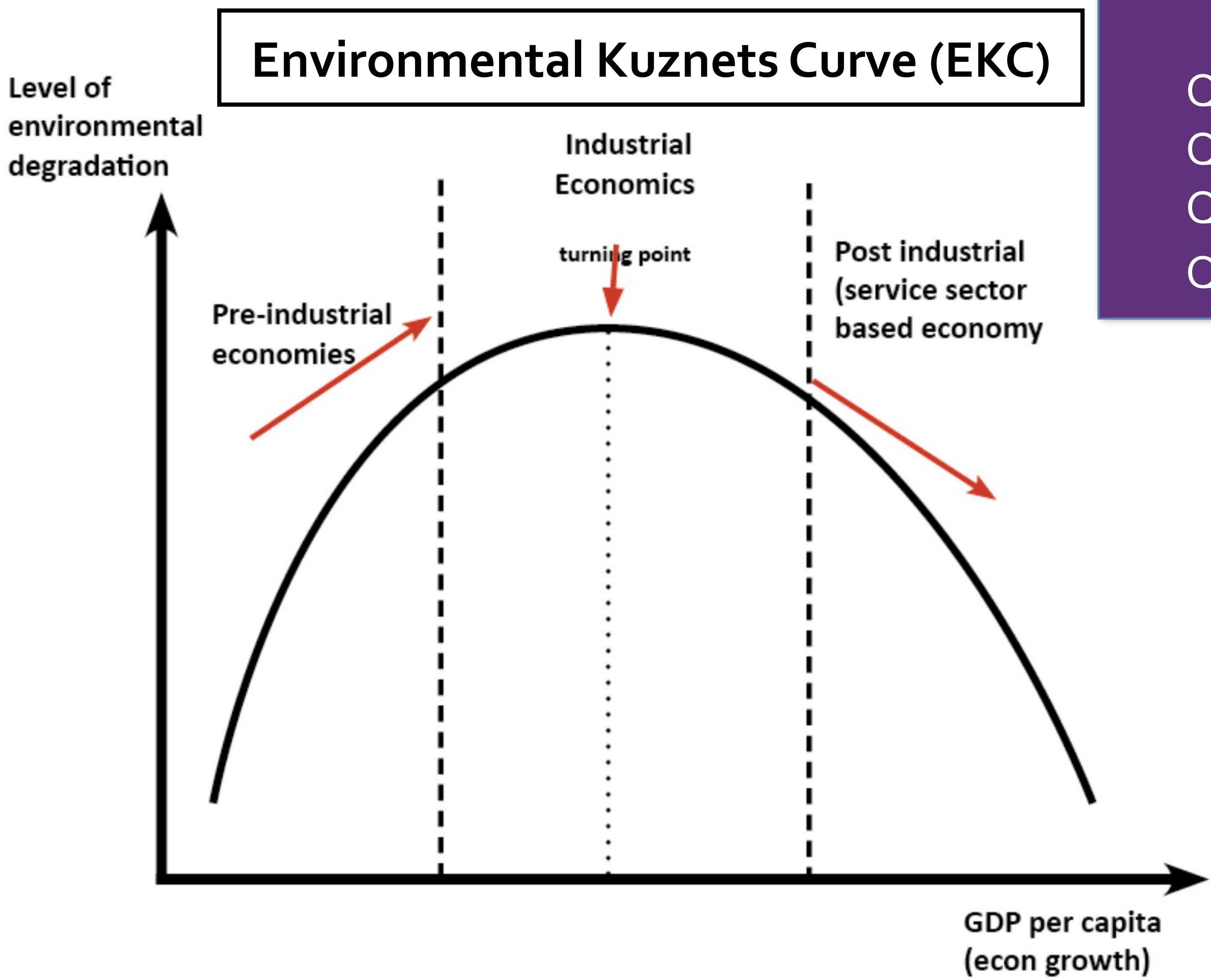
Insufficient constraints at NH high latitudes for 2017-2018 (unhealthy OMI only). Will be revised using OMI+GOME-2.

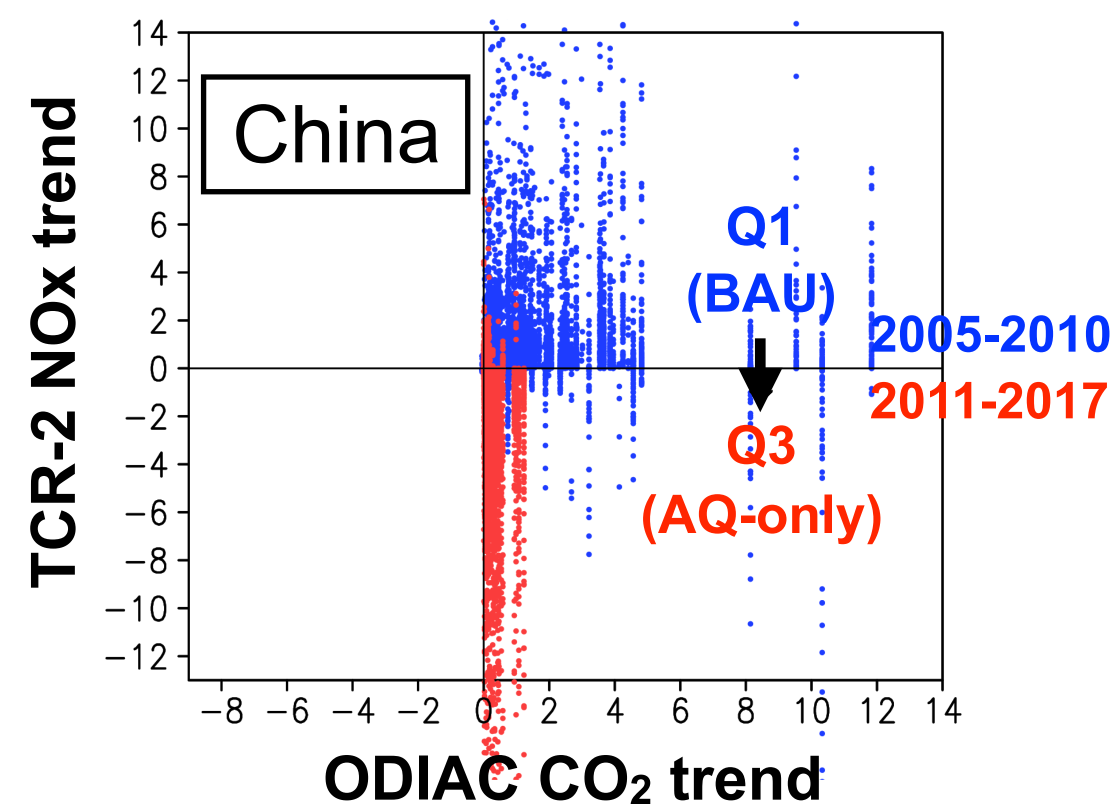
AQ/Carbon co-evolution

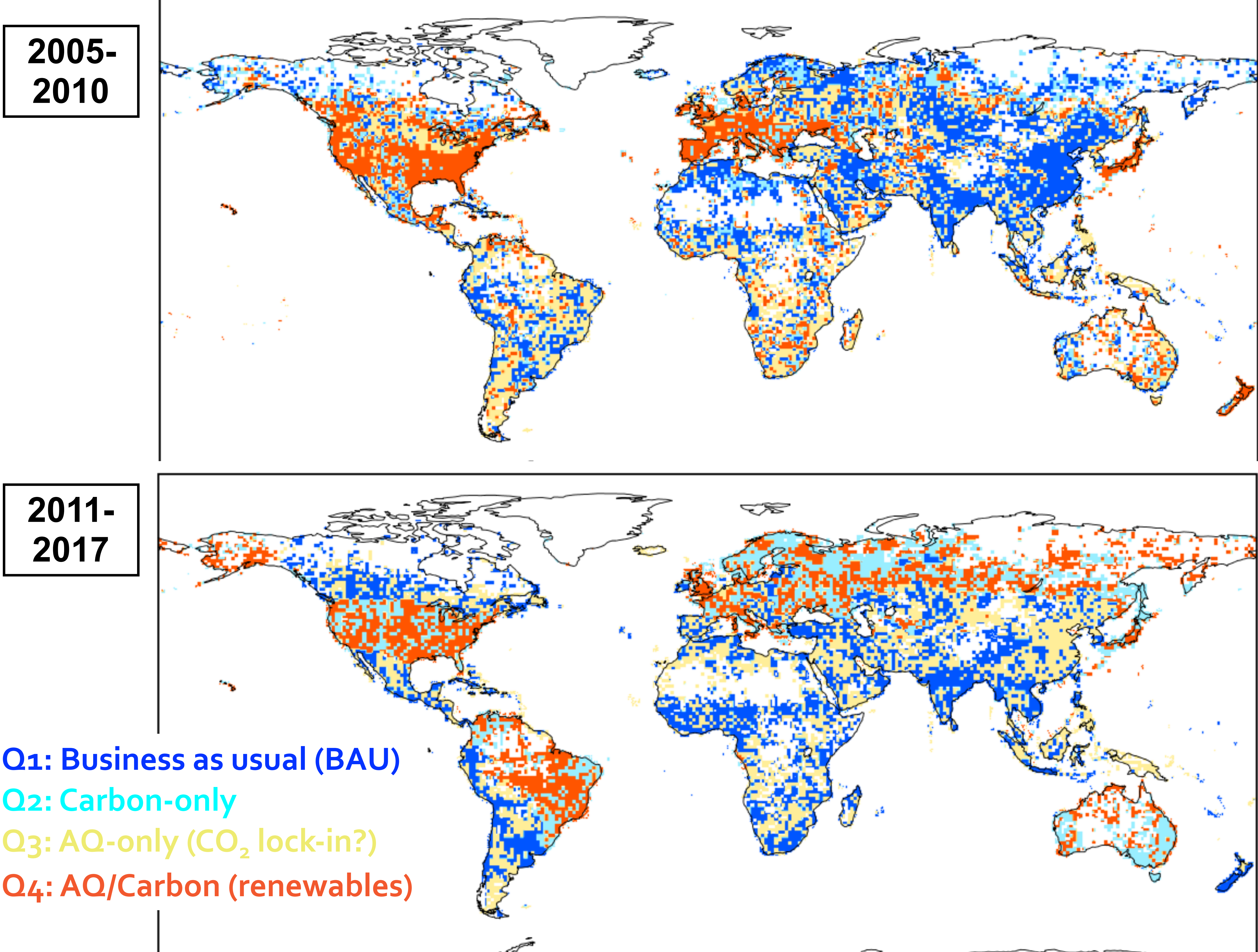
How will changes in air quality mitigation impact carbon emissions?



Q1: Business as usual (BAU)
Q2: Carbon-only
Q3: AQ-only (CO_2 lock-in?)
Q4: AQ/Carbon co-reduction (renewables)






2005-
2010
2011-
2017
Q1: Business as usual (BAU)
Q2: Carbon-only
Q3: AQ-only (CO2 lock-in?)
Q4: AQ/Carbon (renewables)

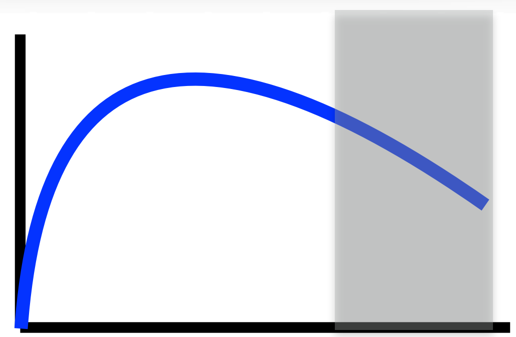
CO_2 flux prediction using top-down NOx emissions

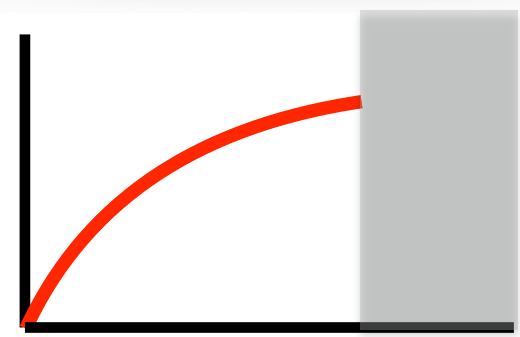
Air quality (NOx)

GHG (CO_2)

Top-Down

quick update





Bottom-up

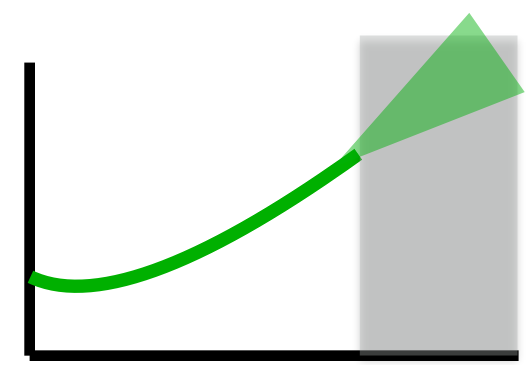
slower update

Time

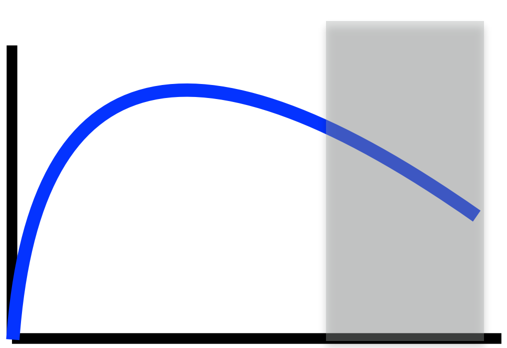
Variations in emission ratios (CO_2/NOx)

(gradual changes in technology and regulation)

+Kalman filter prediction and error estimation

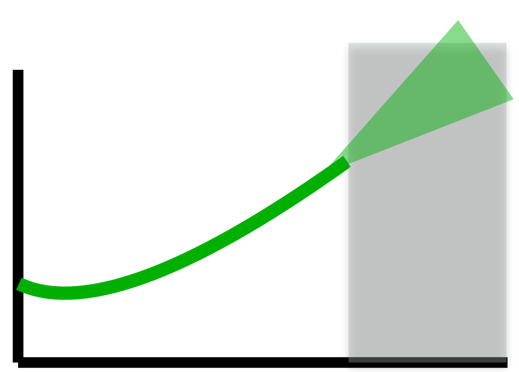


Top-Down NOx emission



x

Emission ratio



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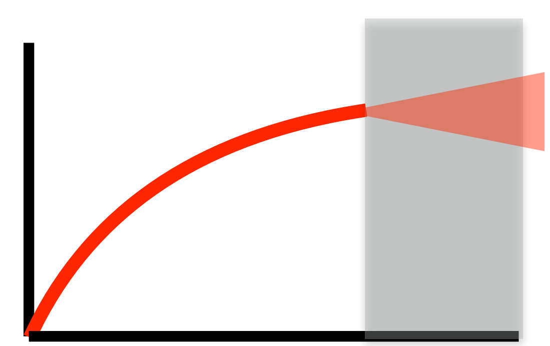
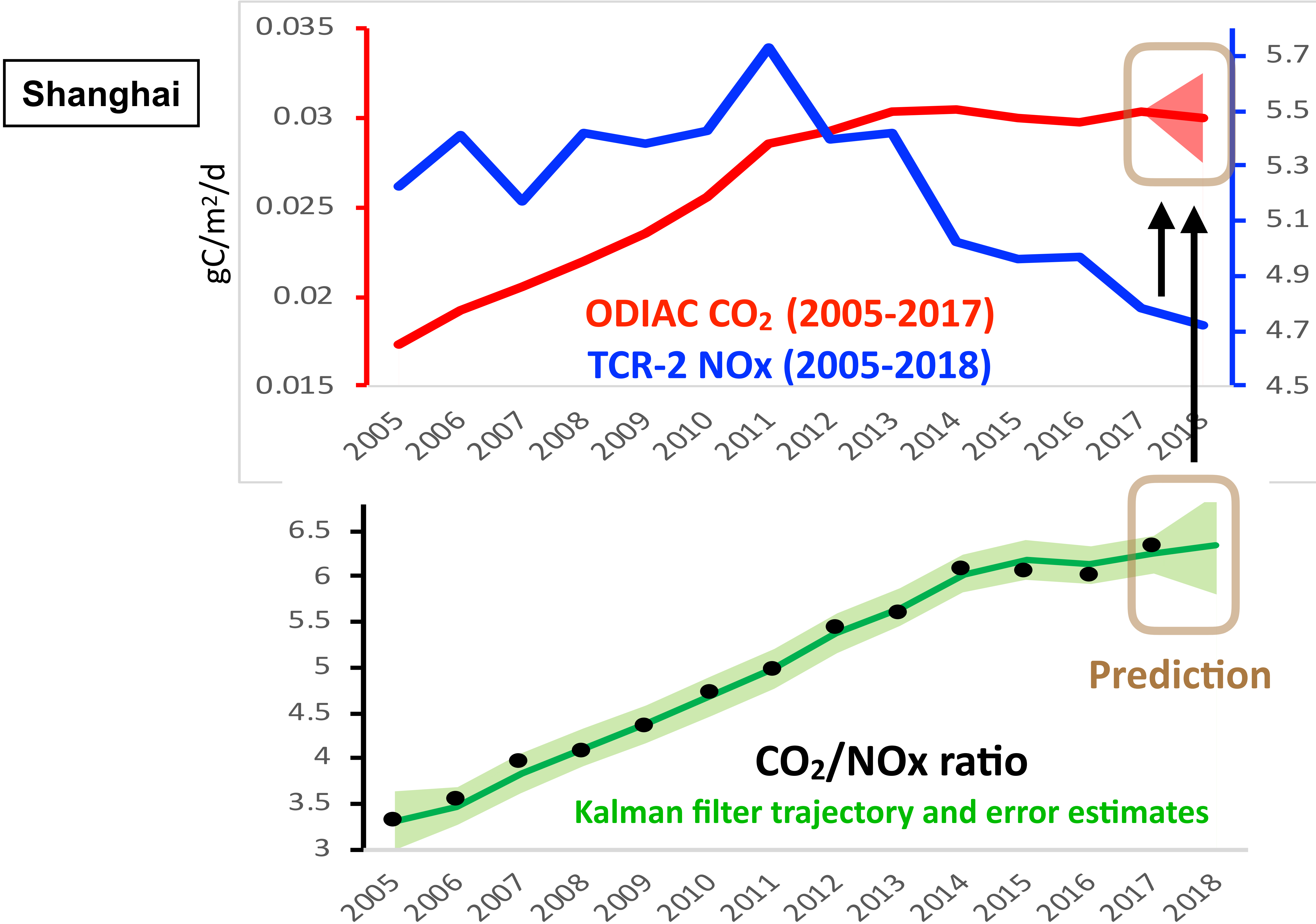
CO_2 flux prediction

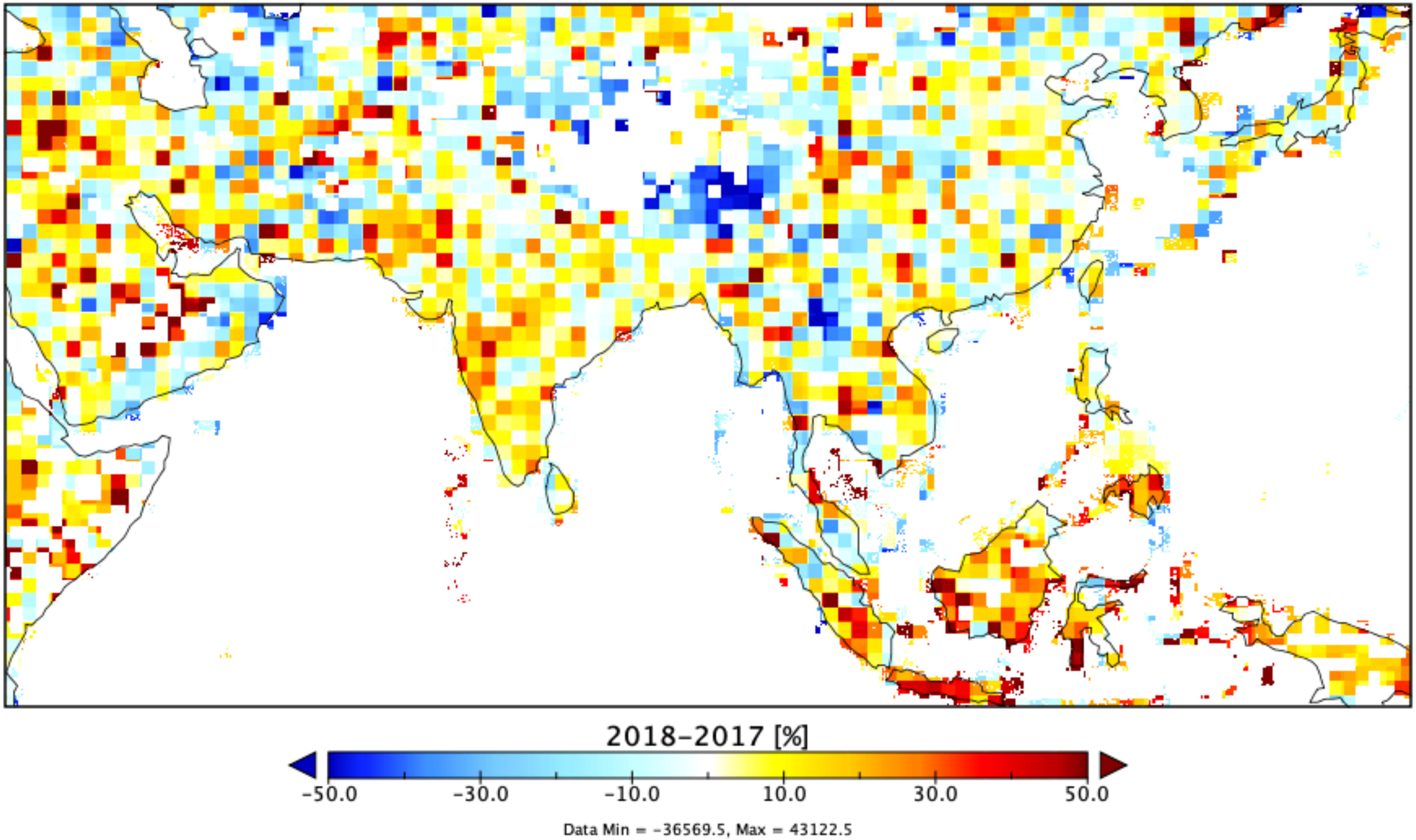




Strong variations in emission factors for India, SE Asia, and the Middle east

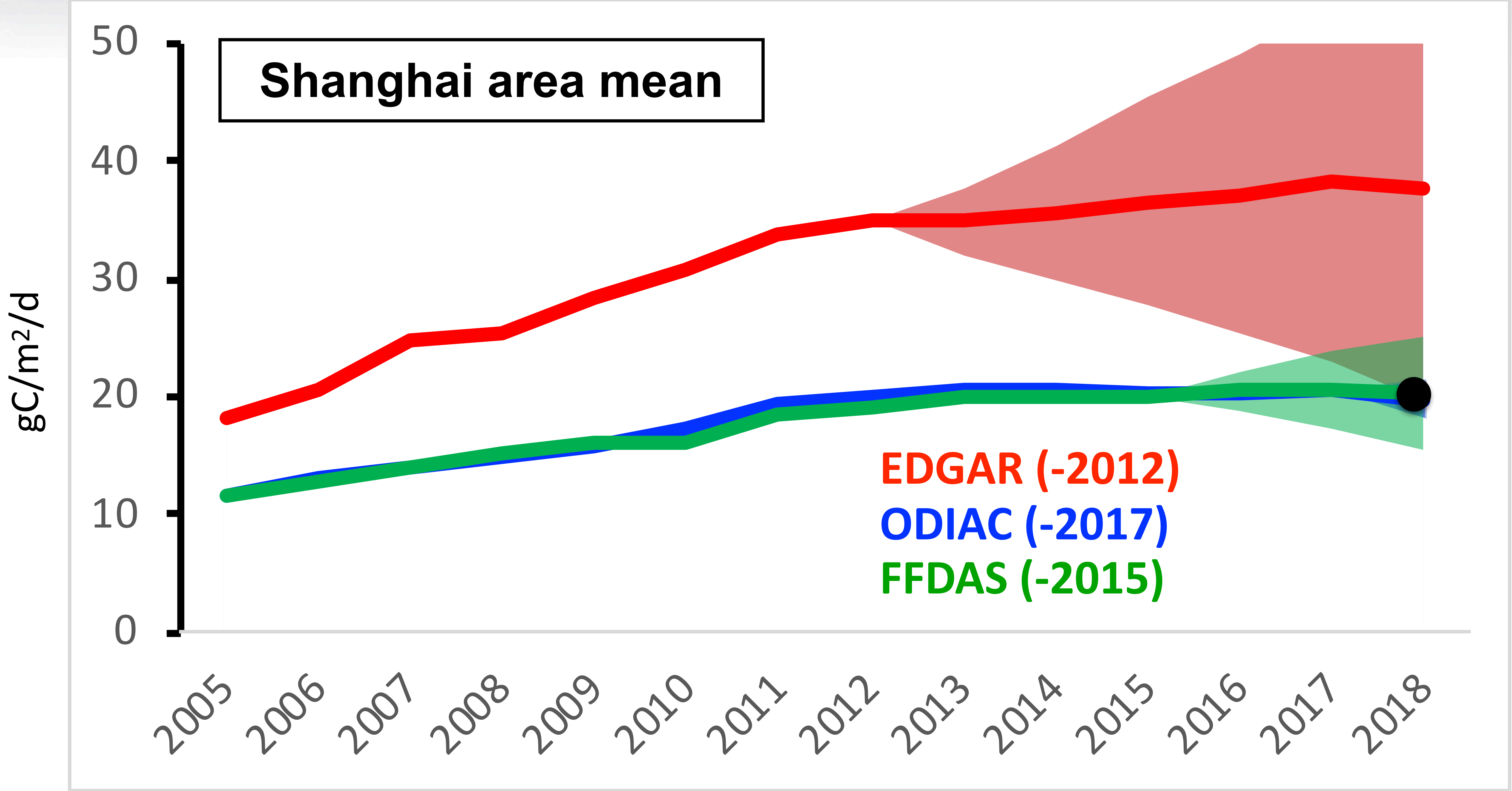
→ ***Evaluation of emission inventories, understanding of emission processes***

FF CO2 fluxes: 2018(predicted)-2017 (ODIAC)



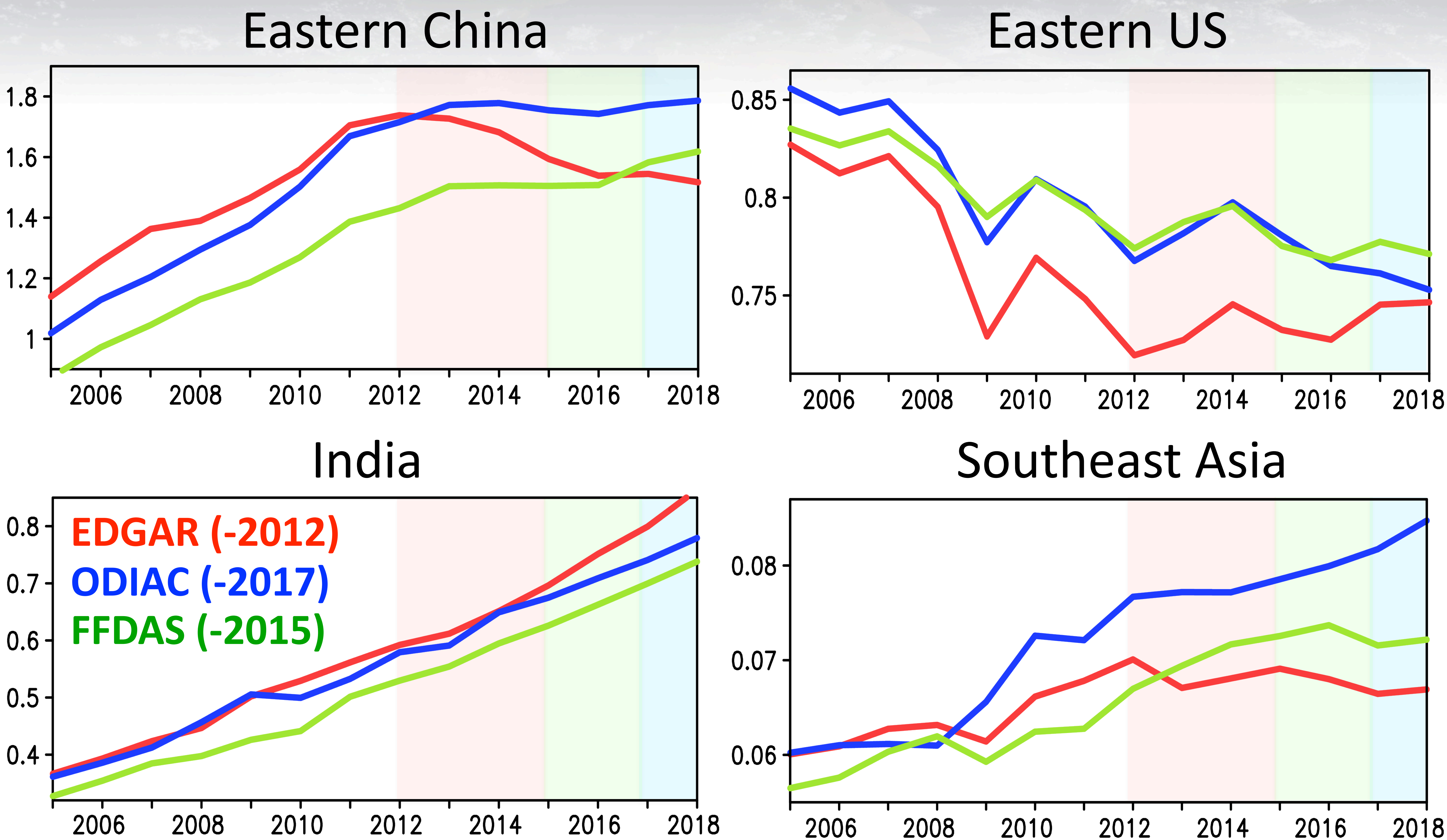
How will ODIAC 2018 look like? 😏

CO_2 flux estimations: Multi-inventories integration



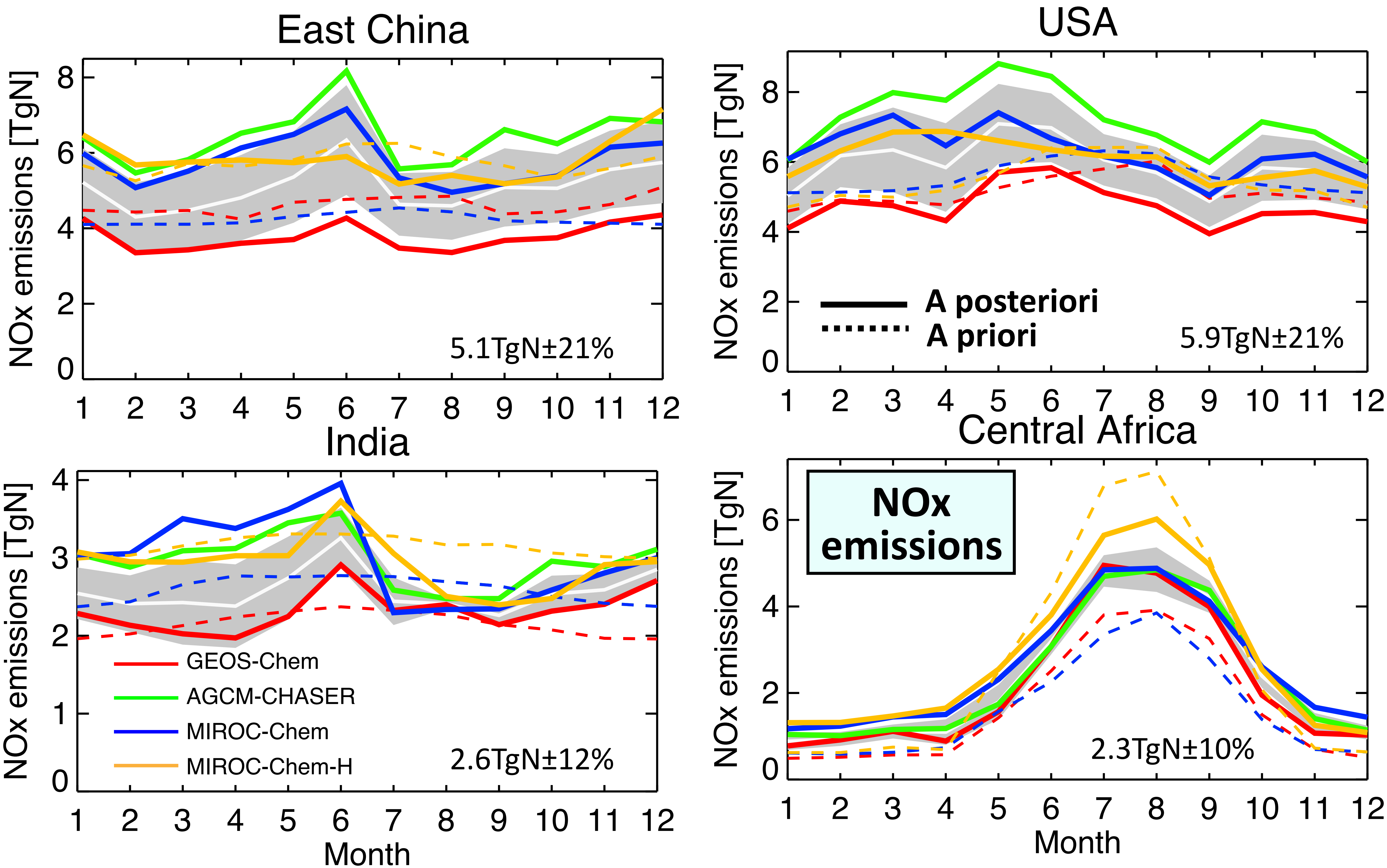
Multi-inventories mean (uncertainty-weighted) for 2018 : <u>19.9 ± 1.5 gC/m²/d</u>

ODIAC 2005-2017 & predicted 2018 CO2 fluxes (PgC/yr)



NOx emission uncertainty → CO_2 flux uncertainty

MOMO-Chem : Multi-mOdel, Multi-cOnstituent CHEMical DA



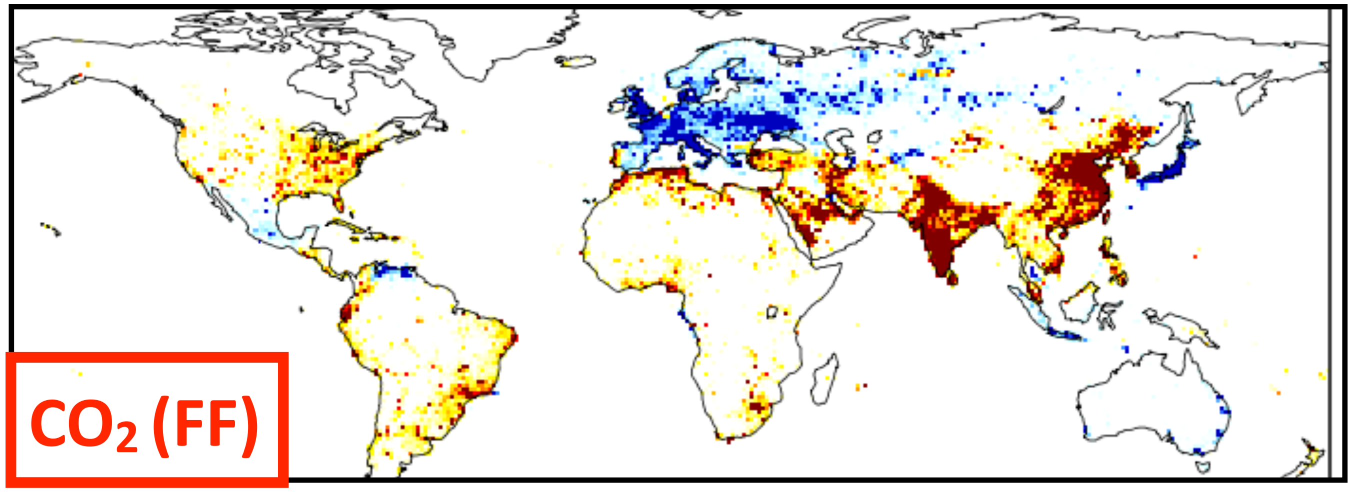
***Multi-model SD**: 13–31% for industrialized areas and 4–21% for BB areas*

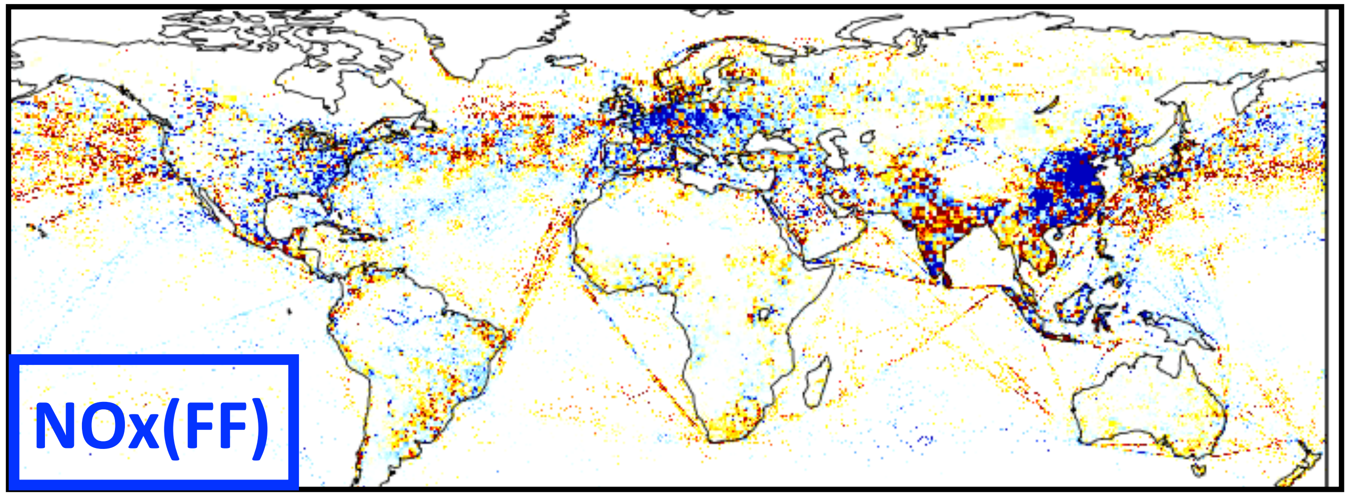
Miyazaki et al., to be submitted

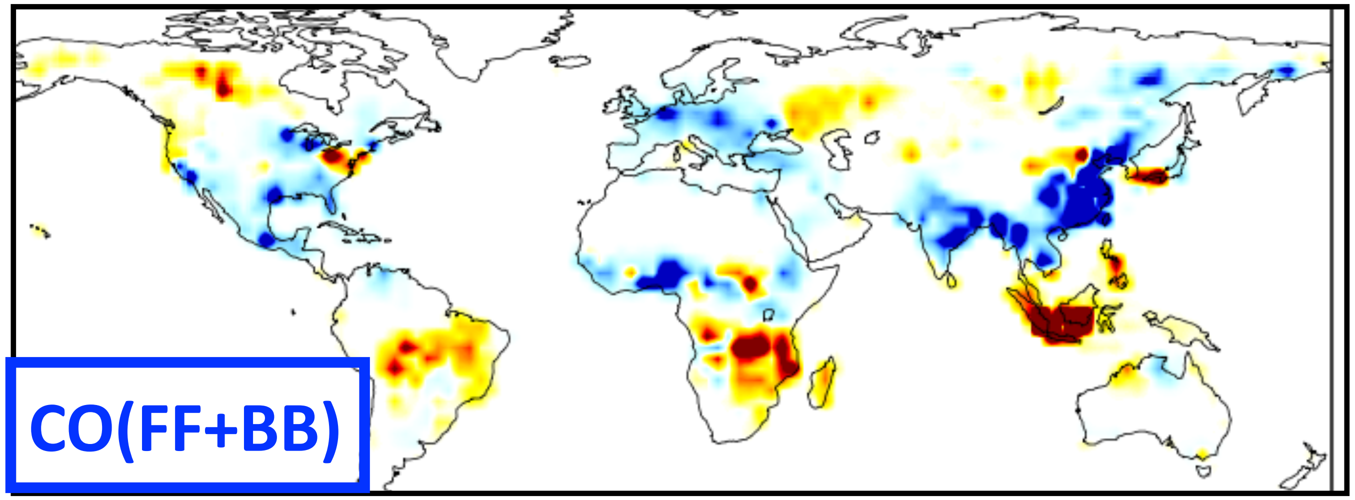
Multi-species constraints on FF CO_2 flux

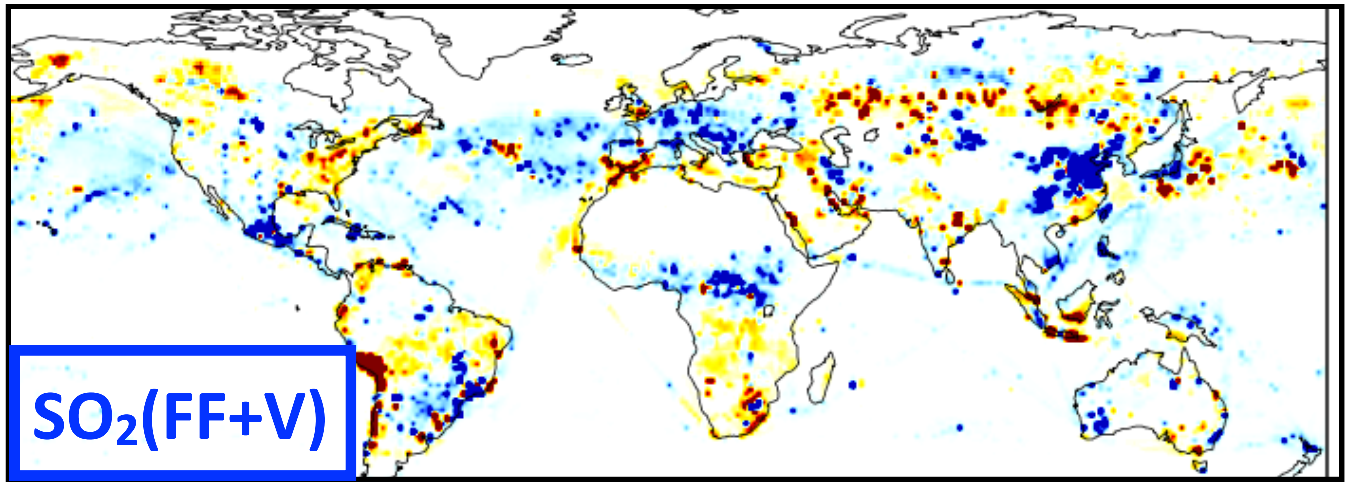
Different aspects of the combustion technology are expected to affect those emissions

- **NOx**: strongly depend on the temperature of combustion (more NOx at high T)
- **CO**: can be regarded as a measure of the incompleteness of combustion processes
- **SO_2**: Linked to the burning of fossil fuels. Also, strong emissions from volcanic eruptions.









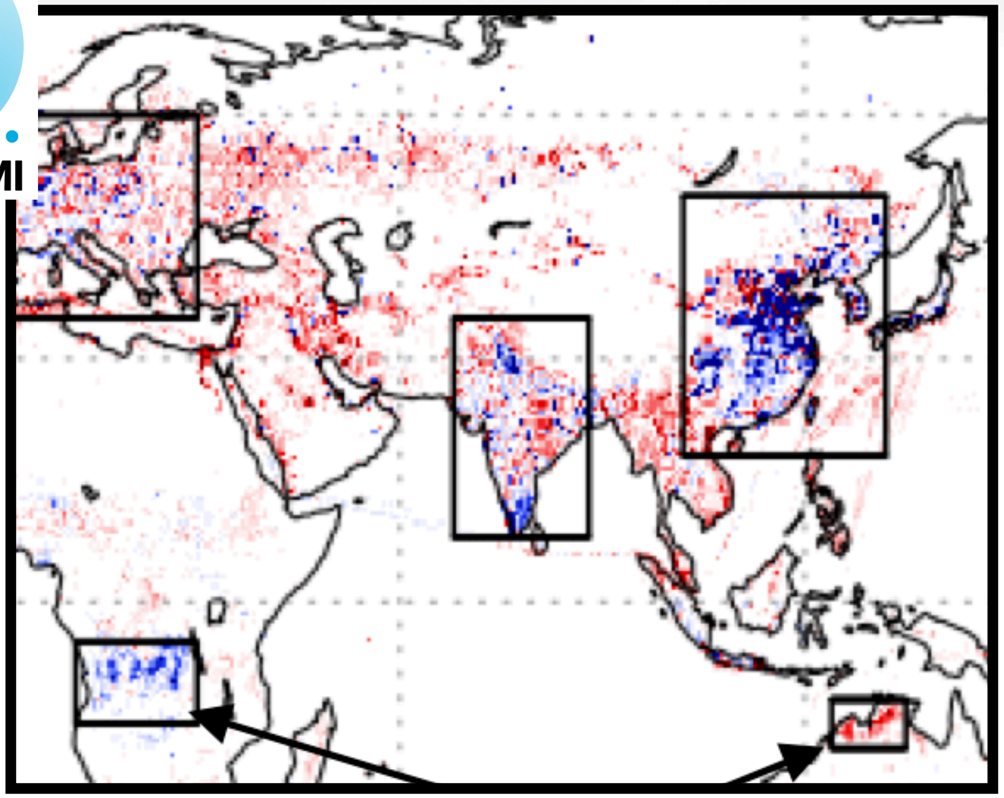
2011-2015 trends

Multi-species regressions using chemical reanalysis products will provide comprehensive constraints on FF CO2 fluxes and to improve bottom-up inventories

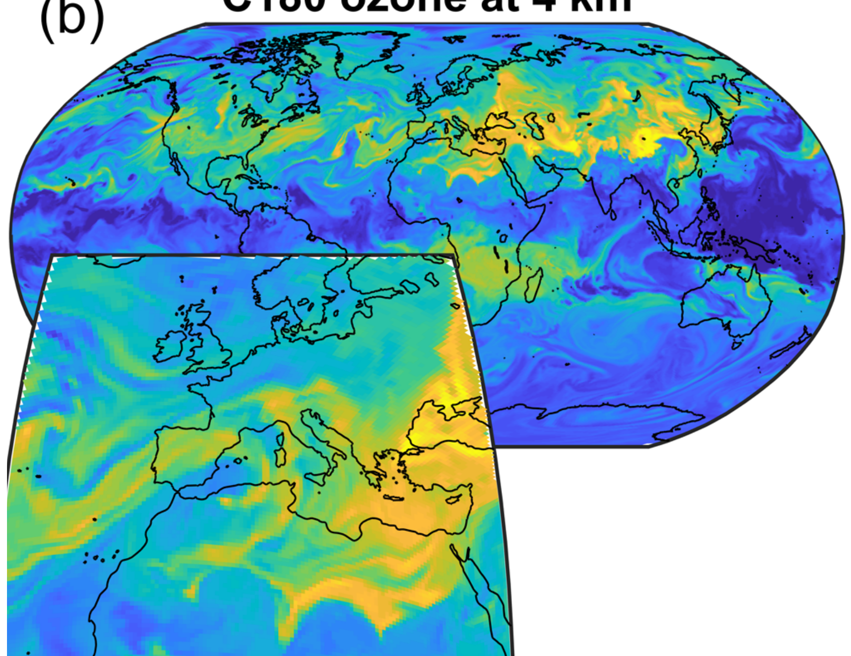
High-resolution multi-species joint emission analysis

Global TROPOMI NO_2 DA at 0.56 deg resolution
(Sekiya et al., poster)

TROPOMI



(b) C180 ozone at 4 km



GEOS Chem

GCHP-EnKF developments at JPL

CEOS
Committee on Earth Observation Satellites

OCO-3 | Sentinel-7 | GeoCarb

TROPOMI | CrIS

TEMPO | GEMS | Sentinel-4

Joint emission estimation
Joint DA analysis

↓

Bottom-up inventories

Conclusions

- $FF\ CO_2$ fluxes can be predicted for the most recent years based on Kalman filter trajectories of emission ratios, by combining bottom-up GHG inventories with top-down estimate of proxy species from chemical reanalysis, which extend GHG inventories.
- The multi-GHG inventories and multi-model chemical reanalyses (MOMO-Chem) provide integrated information on GHG/AQ variations and their uncertainty.
- The obtained long-term changes in emission ratios could suggest developments of multi-species bottom-up inventories, such as REAS and EDGAR.

Future works:

- Multi-species constraints and AQ-GHG joint emission optimizations though high-resolution DA of the existing/future satellites
- Emergent constraints on the chemistry-climate system and carbon cycle